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TRAVEL OF SYNTHETIC DETERGENTS WITH PERCOLATING WATER

Stephen A. Klein, et al

California University
Berkeley, California

February 1964

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TRAVEL OF SYNTHETIC DETERGENTS WITH PERCOLATING WATER

Third Annual Report

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SANITARY ENGINEERING RESEARCH LABORATORY
COLLEGE OF ENGINEERING
AND
SCHOOL OF PUBLIC HEALTH
UNIVERSITY OF CALIFORNIA
BERKELEY

SERL REPORT NO. 64-2

TRAVEL OF SYNTHETIC DETERGENTS WITH PERCOLATING WATER

Third Annual Report

Proposal No. UCB-Eng 1618
Research Grant WP-207-C2

By

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February 1964

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College of Engineering
and
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University of California
Berkeley

SERL Report No. 64-2

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I. INTRODUCTION

NEED FOR INVESTIGATION

Persistence of synthetic detergents, particularly alkylbenzenesulfonate (ABS), in natural waters has received wide publicity and has focused interest on the fate of these materials in waste water treatment plants and on their buildup in water supplies. Research has shown that where secondary treatment is utilized, ABS removals of 50 to 60 per cent occur, whereas primary treatment alone removes but about 2 per cent. The result is that 5 to 10 mg/l of unaltered detergent survive sewage treatment. Usually, this is diluted sufficiently in receiving waters to pose no problem, but wherever the concentration of ABS in flowing water exceeds 1 or 2 mg/l, public complaints of foaming are commonly heard. Instances of foaming surface waters occur both in the intensely re-used river waters of the East and Midwest and in small heavily burdened streams in all populated regions of the U.S.

Recently, concern over the possibility of contamination of ground waters by synthetic detergents has been widespread among those responsible for the management and protection of water resources. This concern derives from the post-World War II trend of population movement from cities to subdivisions lying beyond the reach of public sewers. Consequently, some 30 million people must rely on septic tanks for modern sanitation. The fear is that once ground waters are contaminated to a degree sufficient to produce frothing, the nuisance may persist long after the source of contamination disappears simply because, unlike the surface waters, ground waters are very slowly flushed out.

The major question then becomes: To what degree are detergents removed from wastes passing through septic tanks and attendant percolation systems? Detectable concentrations of ABS in ground waters demonstrate that degradation is incomplete. Furthermore, frothing of water obtained from wells in sewage-polluted strata is not an uncommon occurrence. It is therefore important to study the interrelationships of synthetic detergents and septic-tank systems.

In the western United States, other opportunities exist for the exposure of ground water to detergent contamination from sewage effluent. In semi-arid areas, water conservation is practiced by reuse of waste water for agricultural irrigation. Ground water recharge either by direct injection into aquifers or by surface spreading is also currently practiced on a modest scale and is advocated in much larger installations. Therefore, research on factors influencing detergent adsorption and degradation in both saturated and unsaturated soils is essential.

NATURE AND SCOPE OF INVESTIGATION

The Investigation was divided into three phases, each covering one year of experimental work. It was conducted by the Sanitary Engineering Research Laboratory of the University of California under the terms of Research Grant WP-207 awarded by the National Institutes of Health to the Regents of The University on the basis of proposals UCB-Eng-1409 and UCB-Eng-1618 for an investigation of the "Travel of Synthetic Detergents With Percolating Water."

Phase One of the Investigation was directed to a determination of detergent removal by adsorption and other phenomena in both the biologically active and the biologically inactive strata of pervious soils. Results of this phase were reported in the First Annual Report [1], which dealt with experiments on adsorptive phenomena during saturated and unsaturated flow through five agricultural soils and through aquifer material from the University of California's experimental recharge well field. These experiments were conducted in laboratory columns loaded with feed solution containing various ions normal to sewage effluent, together with one mg/l ABS and tracer amounts of ABS^{35}. From them the following conclusions were drawn:

1. All soils examined displayed an ability to adsorb ABS. Adsorption or retention was greatest in the top zone, probably as a result of selective entrapment of the larger ABS molecules. (ABS used in the investigation was made from alkylbenzene having from 12 to 16 carbons in the alkyl group.)

2. All soils showed a tendency for continued adsorption of ABS during periods of static contact between soil and ABS-bearing liquid.

3. The most adsorptive soils were those with the most uniform distribution of particle sizes.

4. In soil columns 25-cm deep and 2.5-cm in diameter, the most adsorptive soils removed 50 per cent of the ABS present in the first liter of liquid percolating through it. (The range for various soils was from 66 to 22 per cent removal.) After 5 liters, only about 5 per cent of the influent ABS was removed.

5. All soils exhibited an early breakthrough of ABS^{35}, the more permeable soils (least adsorptive) requiring the shortest period of time. The ratio of effluent to influent ABS reached 90 per cent in about one-half the time required for 100 per cent breakthrough.

6. There was virtually no difference between the biologically active and biologically inactive soils in their ability to adsorb ABS under conditions of either saturated or unsaturated flow.

7. Some biodegradation of ABS occurred during periods of resting of biologically-active unsaturated soil, but the rate was too small to be of consequence in preventing breakthrough of infiltrate ABS to ground water, the rate of buildup to the limit of

adsorption on soil being hundreds of times that of reduction by biodegradation. Degradation was confined largely to the top one inch of the soil column.

8. Aquifer sand from the Richmond Field Station recharge well-field adsorbed ABS in amounts similar to that found for Oakley sand, the least adsorptive of the five agricultural soils utilized.

9. In the range of concentrations of ABS used in the experiments (0.001 to 10.0 mg/l), adsorption was directly proportional to the ABS concentration in the infiltrating liquid.

10. ABS adsorbed on soil was freely exchanged with ABS in the percolating liquid in a manner similar to the Langmuir adsorption isotherm, in which gas molecules are continuously adsorbed and desorbed from a solid surface.

11. Eighty per cent of adsorbed ABS was readily leached from the soil by detergent-free water. Continual application of leaching water produced a further, but slower, reduction in ABS content of the soil, down to some minimum residual value.

12. The distribution of ABS throughout the soil column indicated that molecular entrapment between particles of clay was responsible for that part of residual ABS retained after leaching, the greatest retention occurring at the surface zone with uniform retention at lower horizons.

13. Analysis of soil by zones demonstrated that below the surface zone (abnormal for reasons of selective molecular entrapment of ABS) adsorption of ABS with depth conformed closely to the plate theory, which postulates that the solute adsorbed by soil at any horizon is proportional to the concentration of the solute reaching that horizon.

14. The degree of adsorption of ABS on soil, while appreciable in amount, was not sufficient to prevent an ABS breakthrough in a short period of time comparable to that needed for waste disposal projects. Furthermore, adsorbed ABS could be expected to continue to reach ground water in decreasing amounts after application of ABS was discontinued.

15. Under equilibrium conditions the ABS content of a ground water might be used as an index to the degree of recycling of waste water which occurs in any individual case.

16. The results of the experiments reported conformed with what might be expected on the basis of theoretical concepts of adsorption phenomena and known characteristics of anionic detergents.

During the second phase of the Investigation, the relationship of plants to ABS was studied with regard to uptake and concentration of ABS in plant structure, as well as the effect of ABS on plant growth.

Results were reported in the Second Annual Report [2]. Two species of plants--sunflower and barley--were grown in water culture at ABS concentrations of 0, 10, and 40 mg/l, and three species--sunflower, barley, and Lupinus albus--were grown in soil at ABS concentrations ranging from 0 to 50 mg/l. In soil studies water solutions of ABS were compared to primary sewage effluent containing from 0 to 15 mg/l ABS in addition to the normal burden of ABS present in sewage. Effect of ABS on germination of corn and Lupinus albus seeds was also observed.

Although it was found that ABS causes a severe plant growth inhibition in water culture, only one specimen (sunflower) was adversely affected in soil studies, and this occurred in unfertilized soil irrigated with a tap water solution of ABS. In fertilized soils no growth retardation occurred, and plants irrigated with sewage surpassed those receiving water. Despite added amounts of ABS in the sewage and regardless of soil fertilization practices, sewage effluents produced far greater crop yields than normal irrigation water. It was concluded, therefore, that the beneficial effects of sewage nutrients outweigh the adverse effect of ABS to plant growth.

Other conclusions drawn from these studies were:

1. In water culture studies, ABS concentrated to a considerable degree in plant roots (up to 9 per cent in sunflowers and 2 per cent in barley on a dry weight basis) and to a lesser extent in stems and leaves (up to 0.2 per cent).

2. In water culture, degradation products of ABS were present primarily in the stems and leaves (up to 0.2 per cent) with only traces present in the roots.

3. Chlorosis of the leaves was evident in water culture studies--particularly in sunflowers grown in 10 mg/l ABS.

4. In soil studies, sunflowers grown at 5 mg/l ABS were unaffected, but those at 10 mg/l were 30 per cent retarded and at 50 mg/l were 65 per cent retarded.

5. Sunflowers receiving primary sewage effluent (containing 4.6 to 12.7 mg/l ABS) flourished in comparison to control plants receiving tap water and grown in unfertilized soil (7-fold increase in mean fresh weight).

6. Concentration of ABS in sunflowers grown in soil was small (less than 0.01 per cent in the stems and leaves), and ABS degradation products were present in slightly greater concentrations (0.02 to 0.07 per cent in the stems and leaves).

7. It was calculated that approximately 10 per cent of the ABS content of the soil was taken up by sunflowers (including estimated root ABS concentration) irrigated with sewage effluent.

8. In soil studies the only plants to be affected by ABS were sunflowers grown in unfertilized soil. The other two species (Lupinus albus and barley), grown in fertilized soil, showed no sensitivity to ABS at concentrations up to 20 mg/l. It may then be true that plant growth is retarded by ABS only in a nutrient-deficient soil.

9. Only a trace (less than 0.001 per cent) of ABS was found in the edible portion of barley irrigated with up to 25 mg/l ABS. Degraded ABS was found in concentrations on the order of 0.01 per cent.

10. In the seed germination stage Lupinus albus was increasingly stimulated by ABS in concentrations ranging from 5 to 20 mg/l. Corn seeds were increasingly retarded by ABS at concentrations above 25 mg/l.

No further work with plants was deemed necessary, since the results of plant-ABS relationships were quite conclusive.

The rusults herein reported in detail were derived from experimental work completed by the authors in the third and final phase of the study, during the period 10 October 1962 to 30 September 1963. The major objectives of this work were:

1. To determine the effect of ABS degradation in soil systems of such factors as frequency of dosing, hydraulic loading, and waste pretreatment.

2. To evaluate the physical and chemical characteristics of effluents derived from septic tanks and from primary treatment, in terms of their effect on ABS degradation during percolation through soil systems.

3. To examine the fate of polypropyl ABS in septic tanks and septic-tank percolation systems to determine the ground water pollution potential of ABS-bearing sewage.

4. To establish a base line for evaluating "biologically soft" detergents soon to be proposed as a replacement for polypropyl ABS in household use.

Laboratory soil columns were operated over a six-month period to determine the effect of loading parameters on ABS degradation. Both septic-tank effluent and primary settling-tank effluent were percolated through these systems at several dosing frequencies and at various hydraulic loadings to establish the optimum conditions for degradation to occur.

Both types of effluent were also subjected to gentle aeration in glass cylinders for several months. The die-away of ABS under these conditions was observed and compared with results obtained in soil systems. These data enabled differentiation between physical and chemical waste characteristics as they affect ABS degradation in aerobic treatment.

Finely ground sewage was passed through a model septic tank over a three-month period to observe the fate of polypropyl ABS. Intermittent dosing on a schedule of six times per day was used to simulate the variable loading applied to septic tanks in actual practice. Both radioassay and colorimetry were employed to trace ABS through this system.

ACKNOWLEDGEMENTS

The project staff is indebted to Dr. John Winneberger and Mr. Arnold Menar for their consultative services on septic tanks, and to Mr. Deh-Bin Chan for his assistance in laboratory analysis.

II. MATERIALS AND METHODS

SEWAGE

Raw sewage used in the investigation was obtained from a trunk line of the City of Richmond from whence it is pumped at a rate of 40 gpm to the Sanitary Engineering Research Laboratory's primary sedimentation tank. It contains some wastes from light industry, but is primarily residential waste.

SOIL

Oakley sand, a soil often used in previous studies, was employed in experiments with soil columns. It is a slightly acid soil derived from sandy, mixed alluvium and characterized by excellent subsurface drainage. Its particle size distribution is as follows: 12% clay, 1% silt, 9% very fine sand, 33% fine sand, 41% medium sand, and 2% course sand. Other notable characterisitcs are a porosity of 41%, a denisty of 1.63 g/ml, an exchange capacity of 2.3 me/100 g, an organic carbon content of 0.5% and an inorganic carbon content of 0.00%.

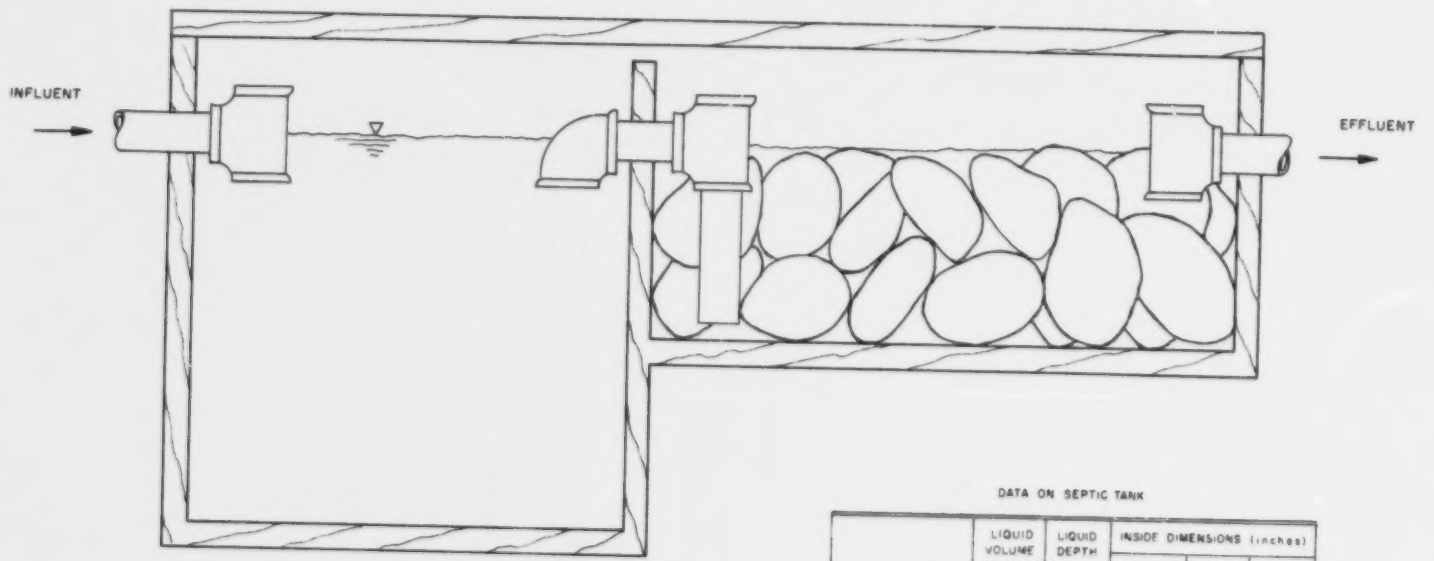
SOIL COLUMNS

Soil columns such as described in the Second Annual Report [2] were used for experimental purposes. These consisted of glass cylinders 3.81 cm in diameter and 94 cm in length. Packed in each cylinder was 1281.5 g of Oakley Sand to provide a soil column 77.7 cm in length overlaying an underdrain consisting of 3 cm layers each of pea gravel, Montery coarse, and Monterey fine sand. The soil columns were packed uniformly by pouring dry soil into the cylinders at a constant rate while tapping the outside of the cylinder with a rubber stopper. An aluminum foil wrapping around the cylinder served to exclude light from the soil column.

SEPTIC TANK

A two-chambered model septic tank located adjacent to the sedimentation tank served the needs of this study. It was constructed of 3/4-inch plywood and protected from the corrosive action of sewage by a lining of fiberglass and resin. A schematic drawing of the tank, presented in Figure 1, gives its inside dimensions.

Inasmuch as stone beds have been observed to aid sedimentation by reducing the surge of influent flow, the second chamber of the septic tank was filled with smooth cobblestones ranging in size from 3 to 5 inches in the greatest dimension and 2 to 3 inches in the least.



DATA ON SEPTIC TANK

	LIQUID VOLUME (liters)	LIQUID DEPTH (inches)	INSIDE DIMENSIONS (inches)		
			LENGTH	WIDTH	DEPTH
FIRST CHAMBER	36.1	12	13.5	13.5	16
SECOND CHAMBER	9.6	6	18.0	13.5	9

NOTE TANK CONSTRUCTED OF 3/4" PLYWOOD

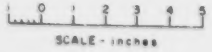


FIGURE 1. MODEL SEPTIC TANK

Solenoid-operated spring-loaded valves controlled flow in the influent line of the septic tank. Since the presence of an obstructing sewage solids particle in the valve seat can cause a valve to remain open until subsequent energizing of the solenoid releases the praticle, two valves were connected in series. Although such obstruction are rare, a large error can be created by this occurrence in experimental work. It is highly unlikely that two valves in series would stick open at the same time, and the arrangement worked satisfactorily throughout the investigation.

DOSING APPARATUS FOR SEPTIC TANK

Since raw rather than settled sewage was desired in the septic tanks, an intake line was located at the influent end of the SHL sedimentation tank to withdraw sewage. This intake consisted of a 1-inch pipe within a vertical cylindrical cage of 4 x 4 hardware cloth 6 inches in diameter and 5 feet long. The end of the pipe was placed about 2 feet beneath the liquid surface. Sewage was withdrawn and transferred by a garbage grinder, which served both as a pump and as a means of shredding solids to a size compatible with the system. The grinder was activated every twenty minutes by a timer to maintain a fresh supply of ground sewage in a constant-head tank situated above the sedimentation tank. This tank consisted of a 10-gallon fiberglass drum with a large overflow weir and a bottom valve to release excess settled matter. Another line, installed at a point about one-third of the distance from the bottom to the weir crest, afforded gravity flow to a septic tank.

PREPARATION OF ABS

The ABS used in the investigation was prepared in the laboratory by sulfonation of an alkylbenzene comprising a blend of the product of five major producers of this chemical for use in the manufacture of synthetic detergents.

ABS labled with S^{35} was prepared in small batches by sulfonating the alkylbenzene with $H_2S^{35}O_4$. The preparation was carried out in a gloved box.

RADIOASSAY OF SAMPLES

Techniques of radioassay used in the investigation have been previously described [3] by the authors. These made use of planchets suited to assay of samples under both "weightless" and "infinite thickness" conditions.

Planchets used to contain radioactive samples under "weightless" conditons were 2-ml capacity, nickel-plated cups. When infinite thickness was desired, specially machined brass planchets were adopted. They consisted of brass slugs 1-1/2 inch in diameter and 1/8 inch in thickness into which a well, approximately 1/16-inch deep by 1 inch in diameter,

had been machined. S^{35}, precipitated as $BaS^{35}O_4$, was counted in similar planchets, with a well depth of 0.025 inch. The apparatus used to count radioactive samples consisted of an Atomlab Model 21 preflushed flow counter, operated as a Geiger counter in connection with a Tracerlab SC-73 Autoscaler.

III. EXPERIMENTAL RESULTS

REMOVAL OF ABS FROM PRIMARY EFFLUENT BY SOIL COLUMNS

Introduction

In the Second Annual Report, studies showed that intermittent dosing of soil systems was desirable from the standpoint of ABS degradation. Negligible degradation occurred when percolation was continuous, but rest periods induced significant ABS breakdown. There was further evidence that a regular cycle of dosing and resting was preferable to an erratic schedule. To investigate more fully the effect on ABS degradation of dosing schedules, surface hydraulic loading, and character of waste water applied, long-term studies were performed on both primary sewage effluent and septic effluent percolated through soil columns.

Procedure

Each day 1 ml of tracer ABS^{35} was added to 499 ml of primary effluent obtained daily from the SERL primary sedimentation tank. This feed solution was placed in a refreigerator and continuously agitated by gentle stirring with a magnetic stirrer. No additional carrier ABS was added to that already present in the sewage.

From the refreigerator the feed solution was transferred at desired intervals to a soil column by a timer-operated variable-speed pump. A siphon of 96-ml capacity, situated over the soil column, delivered sewage in doses. After one month of operation this siphon was replaced by one with a 65-ml capacity.

Surface hydraulic loading was 8.3 gpd/sq ft (equivalent to 1.4 mgd/acre) when the 96-ml siphon was in use, and this rate was later reduced to 5.2 gpd/sq ft (equivalent to 0.9 mgd/acre) upon installation of the 65-ml siphon.

For the first four months the dosing schedule was once every six hours; it was then altered to once per day. This change in dosing schedule, however, did not affect hydraulic loading. Instead of one siphon load delivered every six hours, four siphon loads were delivered successively in a single dosing interval every 24 hours. Therefore, total liquid volume applied per day was constant at 260 ml during both dosing schedules.

Initially the column was dosed with sewage on the every-six-hour schedule for two weeks to build up a biological growth in the soil. Then tracer ABS^{35} was added to the sewage and sampling of influent and effluent commenced. Total S^{35}, ABS^{35}, and $BaS^{35}O_4$ activity were measured periodically during the 168-day experiment.

Results

Results are tabulated in Table I which shows concentrations in cpm/ml for total and detergent activity in influent and effluent samples. From these the total (S^{35}) and the detergent (ABS^{35}) activity breakthrough is computed in terms of influent concentration (C_o) and effluent and effluent concentration (C) expressed in per cent (C/C_o, %). The difference between total and detergent activity breakthrough is directly attributable to degradation, and the extent of this difference is a quantitative measure of the degree of degradation. This is readily understood by consideration of the fact that total activity, S^{35}, is measured by directly plating out a portion of sample and actually counting all the activity present, but the ABS^{35} activity is measured after a selective ether-HCl extraction which retains only that activity present as unaltered detergent activity. Therefore, degradation will reduce the amount of detergent activity, but will have no effect on total activity.

Breakdown to inorganic sulfate is computed from net $BaS^{35}O_4$ cpm/ml (effluent concentration minus influent concentration) which may be expressed as a percentage of influent ABS^{35} activity in order to represent the proportion of detergent that was completely degraded.

Breakthrough curves of S^{35} and ABS^{35} (shown in Figure 2) reached 100% on the 45th day and in subsequent days exceeded 100%. Breakthrough of more than 100 per cent results from the variable day-to-day ABS concentration in the sewage. Since adsorption is a function of concentration [1], a decrease in ABS concentration of a percolating liquid from one day to the next desorbs ABS from soil and yields a higher effluent ABS concentration than was present in the influent. The result is that C/C_o exceeds 100 per cent, and when plotted appears as an activity peak. The presence of numerous peaks in Figure 2, therefore, indicates a highly fluctuating ABS concentration in the daily feed sewage used throughout the experimental period. Considerable rain during this period caused the incidence of fluctuation to be greater than normal. This did not affect experimental results since desorption of S^{35} activity is constant relative to ABS^{35} activity desorption; hence the net activity difference, which represents ABS^{35} degradation, was unaffected.

In previous studies with soil columns (reported in the First and Second Annual Reports), a simulated secondary effluent served as the infiltrate instead of domestic sewage in order to maintain a constant ABS concentration in the feed. Domestic sewage was used, however, in this experiment to insure growth of a representatively active biological slime.

During the first 49 days the breakthrough pattern was quite similar for S^{35} and ABS^{35}, which demonstrates that degradation was minimal. This is in part attributable to overloading of the system. A condition of overloading was evidenced by the length of time required for ponds to disappear into the soil column subsequent to dosing. Initially, only one hour was required, but later this period lengthened to over 4 hours, severely curtailing the rest period between doses. To

TABLE I

DEGRADATION OF ABC^{32} IN UNSATURATED OAKLEY SAND COLUMN INTERMITTENTLY DOSED WITH PRIMARY SEWAGE EFFLUENT

Day	S^{35} Activity			ABC^{32} Activity			ABC^{32} Degradation (S^{35}, C/C_o - ABC^{32}, C/C_o) %	$BaC^{32}O_4$ (Complete Degradation)			
	Influent cpm/ml	Effluent cpm/ml	C/C_o %	Influent cpm/ml	Effluent cpm/ml	C/C_o %		Influent cpm/ml	Effluent cpm/ml	Net cpm/ml	Net Effluent %
1	1050	27	2.6	969	11	1.4	1.2	0	0	0	0
4	1270	477	37.5	1134	320	27.0	10.5	6	58	32	8.7
15	1411	862	61.1	1340	690	51.4	9.7	16	5	-11	-0.8
2[illegible]	5250	2900	55.2	5060	2385	47.0	8.2	21	85	64	1.3
32	4150	2911	69.6	3800	2500	65.7	3.7	0	93	93	2.4
46	5508	4614	82.9	4977	3167	66.0	20.5	17	116	99	2.1
47	4894	5681	116.8	5905	3707	96.4	28.4	19	59	20	0.7
48	4412	5880	133.4	5484	5824	109.8	24.6	--	--	--	--
49	4547	7141	154.3	5960	4600	128.0	58.3	0	28	28	0.8
9[illegible]	1367	1427	104.2	1102	295	26.7	77.5	10	405	455	41.2
104	1402	1047	74.7	842	139	16.5	58.2	17	167	150	17.8
10[illegible]	1193	1706	142.0	960	475	50.5	91.5	16	339	323	34.4
106	1330	1253	94.2	993	927	93.4	0.8	25	110	85	8.6
109	1412	1467	111.0	1157	379	32.5	78.7	9	510	501	51.0
110	1252	1067	85.2	921	307	33.3	51.9	10	282	272	29.5
112	1329	1170	90.0	1019	320	29.9	60.1	9	302	293	27.4
115	1366	1069	73.3	899	298	33.1	45.2	20	276	256	28.6
116	1068	1195	111.9	846	254	30.0	81.9	4	415	411	48.6
117	1013	1269	124.4	972	323	33.2	91.2	6	383	377	38.8
119	997	1370	137.4	891	367	41.2	96.2	0	19	19	2.1
122	1509	1357	90.1	819	328	40.0	50.1	41	383	342	41.8
123	1343	1609	119.8	805	336	41.7	78.1	38	449	411	51.0
124	1500	1667	128.2	725	313	43.2	85.0	39	487	448	61.8
126	1100	1319	119.9	736	302	41.0	78.9	16	356	340	46.2
130	1220	1481	121.4	710	299	42.0	79.2	18	384	366	51.4
131	1215	1391	114.5	855	241	31.3	83.2	24	398	374	44.8
132	1049	844	80.4	750	234	31.2	49.2	15	254	239	31.9
133	1177	1327	112.3	608	227	37.3	75.0	23	308	315	60.0
136	1378	1166	84.6	578	272	47.1	37.5	16	316	300	51.9
Dosing Changed From Once Every 6 Hours to Once Per Day											
137	1033	1148	111.1	623	345	55.4	55.7	56	289	233	37.4
138	71[illegible]	1049	146.5	755	317	42.0	104.5	23	187	164	21.7
139	1058	1113	105.4	1134	508	44.8	60.6	28	238	210	20.4
143	1459	1282	66.1	1409	648	40.3	25.8	76	314	238	14.8
146	1311	1251	95.9	1156	355	30.7	65.2	26	331	305	26.4
150	1001	1248	114.4	629	322	51.2	63..	209	348	139	22.1
157	805	978	121.3	624	263	42.1	79.2	83	249	166	25.6
158	1040	882	84.8	755	252	33.4	51.4	204	201	87	11.5
159	889	971	109.2	739	242	33.5	75..	43	261	218	29.5
160	821	908	97.9	781	233	29.8	68.1	19	254	235	30.1
161	888	1070	120.5	643	234	36.4	84.1	49	338	289	44.9
164	740	836	113.2	621	231	37.2	76.0	14	215	201	32.4
165	740	862	116.5	707	201	28.4	88.1	11	247	236	33.2
166	755	704	93.2	653	197	30.3	62.9	12	195	183	28.0
168	728	767	105.4	686	19[illegible]	28.6	77.8	11	19[illegible]	185	27.0

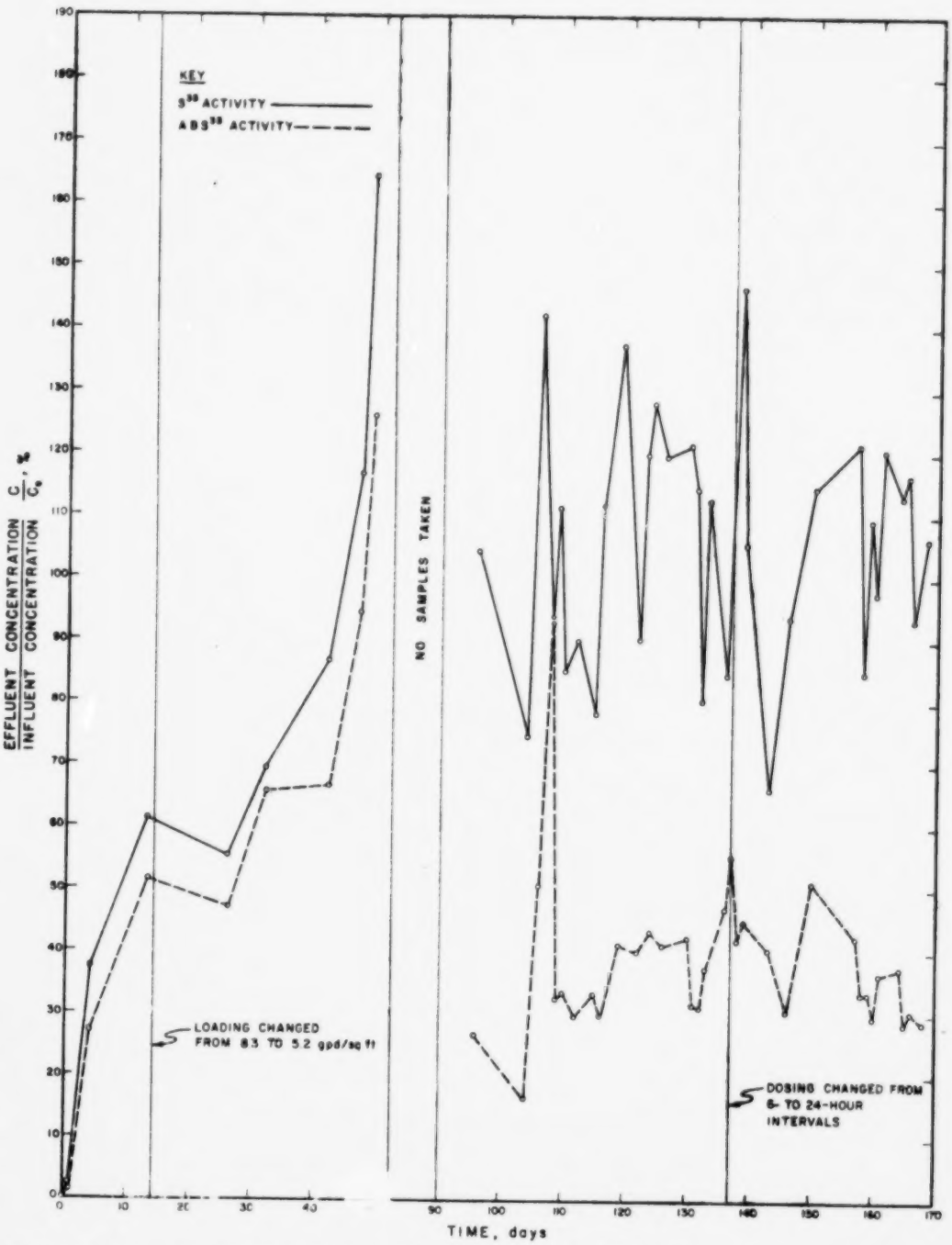


FIGURE 2. BREAKTHROUGH OF S^{35} AND ABS^{35} ACTIVITY IN OAKLEY SAND COLUMN INTERMITTENTLY DOSED WITH PRIMARY-SEWAGE EFFLUENT

correct this situation hydraulic loading was reduced from 8.3 to 5.2 gpd/sq ft on the 14th day.

When the column was operating at steady state from day 96 to 168 ABS^{35} breakthrough was 30 to 40 per cent indicating a removal of 60 to 70 per cent, while S^{35} breakthrough remained on the order of 100 per cent. No significant change in this pattern occurred when the dosing schedule was changed from 6- to 24-hour intervals on day 137.

Figure 3 is a plot of the numerical difference between the breakthrough curves shown in Figure 2. This difference represents total ABS degradation which includes breakdown to inorganic sulfate (shown by the broken line), and partial degradation. Total degradation for the period when 6-hour interval dosing was applied averaged 67.2 per cent (shown by the heavy line) and average degradation to sulfate was 37.5 per cent. By difference, partial breakdown to intermediate products was 29.7 per cent.

During the period of 24-hour interval dosing, total degradation averaged 68.3 per cent, or only 1.1 per cent more than for the 6-hour dosing period. However, degradation to inorganic sulfate was significantly lower at 27.3 per cent (a reduction of 12.6 per cent from the previous period).

Discussion

It is evident that before sizable ABS degradation occurs, a long period of sewage spreading is required. Although the delay seen in the present experiment may be in part attributable to initial overloading of the column, it is questionable whether this was the sole limiting factor, since there was no sharp increase in degradation subsequent to reducing the hydraulic load. In Figure 3 it is apparent that degradation does not rise appreciably until the 40th day, which is 26 days after the load reduction. If an excessive hydraulic load were the only limiting factor, this time lapse would not occur. Apparently, a well-developed biological slime was not formed until the fortieth day. Since there was an initial two-week period of dosing prior to experimental testing, the total time for an active slime to develop was 54 days.

In sewage spreading for ground water recharge or irrigation purposes it is, of course, more practical to operate on the once-per-day schedule than on the four-times-per-day system. Although the latter schedule was slightly superior in terms of complete degradation to sulfate, total degradation was not significantly different. Therefore, there does not appear to be sufficient justification for adopting the more cumbersome 6-hour interval spreading technique in field practice.

It can further be concluded from this experiment that hydraulic loading must be regulated to avoid excessive ponding in order to attain sizable ABS degradation. Also, an initial period of approximately two months is required to build up a satisfactory biological slime in soils. A well-developed slime is capable of degrading 70 per cent of the influent

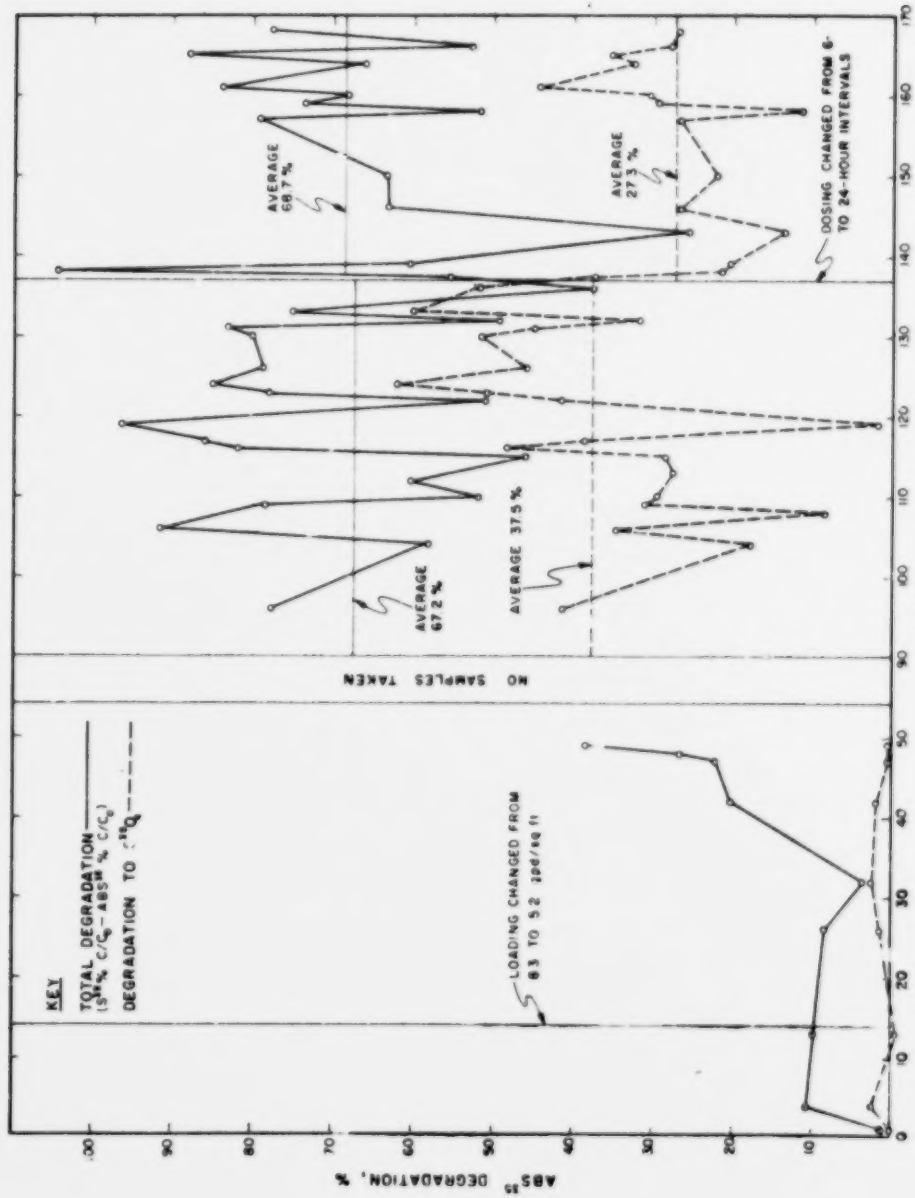


FIGURE 3. DEGRADATION OF ABS^{35} IN OAKLEY SAND COLUMN INTERMITTENTLY DOSED WITH PRIMARY-SEWAGE EFFLUENT

ABS concentration--thirty per cent to partial breakdown products, and 40 per cent to inorganic sulfate.

REMOVAL OF ABS FROM SEPTIC-TANK EFFLUENT BY SOIL COLUMNS

Procedure

Septic-tank effluent was obtained from the model septic tank described in a previous section of this report. Effluent was charged to a soil column at several loading rates and varied dosing frequencies through a 95-ml capacity siphon operated by a timer. Initially, the column was dosed four times per day at 6-hour intervals. Biological growth was built up on the soil at a loading of 384 ml per day (8.3 gpd/sq ft), and the column was operated for 85 days. At the end of this period a more realistic dosing schedule was used. To simulate actual loading of septic-tank percolation fields the number of doses per day was increased to eight and delivered in a 15-hour period. A 60-ml capacity siphon was employed to deliver the doses at regular intervals. The surface hydraulic loading was then increased to 480 ml per day or 10.4 gpd/sq ft.

After 52 days the doses were reduced to 6 per 15-hour period per day at a hydraulic load of 7.8 gpd/sq ft and operated for an additional 34 days.

A biological growth was developed in the columns by two weeks of dosing prior to introduction of tracer ABS^{35} in the feed.

Results

Influent and effluent activity concentration for S^{35}, ABS^{35}, and $BaS^{35}O_4$ are recorded in Table II, and the difference in activity breakthrough of S^{35} and ABS^{35} is plotted in Figure 4 as is degradation to $BaS^{35}O_4$.

Loading during the initial experimental period was identical to that of the primary effluent column (8.3 gpd/sq ft) in the preceding study. Unlike that column, which clogged rapidly, the septic tank effluent column did not become clogged. This phenomena is attributable to the efficiency of suspended solids removal in the septic tank. As might be expected, suspended solids removal is more complete in the 20-hour detention period septic tank than in the 2-hour detention period sedimentation tank. Effluent from the latter was generally on the order of 100 mg/l compared to 60 mg/l in septic-tank effluent.

It is apparent from Figure 4 that a schedule of 4 times per day was the most satisfactory dosing frequency for ABS degradation. Degradation for the period when this schedule was followed averaged 51.8 per cent and degradation to sulfate averaged 19.7 per cent.

TABLE II

DEGRADATION OF ABS^{35} IN UNSATURATED OAKLEY SAND COLUMN INTERMITTENTLY DOSED WITH SEPTIC-TANK EFFLUENT

Day	S^{35} Activity			ABS^{35} Activity			ABS^{35} Degradation (S^{35}, C/C_o - ABS^{35}, C/C_o) %	$BaSO_4$ (complete Degradation)			
	Influent cpm/ml	Effluent cpm/ml	C/C_o %	Influent cpm/ml	Effluent cpm/ml	C/C_o %		Influent cpm/ml	Effluent cpm/ml	Net cpm/ml	Net Effluent %
4	1888	1218	64.	1662	512	22.5	42.2	0	20	20	1.2
5	1895	1509	79.6	1444	486	34.5	45.1	16	158	142	9.9
6	1907	1659	87.0	1479	555	38.0	51.0	6	157	151	10.2
7	1900	1475	75.1	1445	451	31.2	44.2	25	256	255	16.5
20	1850	1452	79.4	1565	565	38.0	41.4	--	--	--	--
33	1245	1431	115.1	1099	475	44.9	70.2	5	561	558	55.8
41	1496	1134	81.4	1354	580	28.8	52.6	4	59	55	4.1
47	1366	1599	108.0	1458	364	25.4	70.6	17	400	385	26.7
55	1657	1013	61.5	457	0	0	61.5	11	177	166	59.8
57	1591	1040	74.8	1100	711	64.5	10.3	5	101	96	8.9
60	1555	1552	101.2	1399	450	30.8	70.4	7	269	258	18.5
61	1505	1068	71.5	1268	735	59.4	12.1	14	55	59	5.1
62	1559	1199	86.5	1197	671	56.0	30.5	9	150	141	11.8
64	1441	1324	91.9	1210	771	65.7	26.2	5	155	148	12.2
67	1541	1297	84.5	1207	615	51.6	42.7	0	125	125	9.9
68	964	1200	126.8	857	705	84.5	42.3	2	157	155	16.1
69	795	1158	149.8	698	695	100.7	49.1	9	107	98	14.2
71	525	1199	229.0	500	815	162.6	66.4	2	155	151	26.2
74	510	971	190.4	440	595	134.2	56.2	5	106	101	22.8
75	466	847	182.5	454	479	110.4	80.1	7	147	140	32.5
76	470	815	175.4	386	409	106.0	67.4	2	128	126	27.5
78	455	612	135.1	399	297	74.4	60.7	2	112	110	27.6
82	459	488	111.2	366	167	42.4	68.8	4	128	124	51.4
83	496	499	100.8	426	160	37.6	63.2	6	124	118	27.8
84	487	485	99.2	459	157	31.5	67.9	6	108	102	25.2
85	891.	579	65.0	725	132	21.0	44.0	9	152	143	19.7
	Dosing Changed From Once Every 6 Hours to 8 Times Per Day (8 Times in 15 Hours With a 9-Hour Rest Period-Loading 10.4 gpd/sq ft)										
89	985	1004	108.5	288	192	67.7	41.8	32	125	93	40.8
99	564	449	79.6	506	217	42.7	36.9	102	192	90	17.7
102	824	621	75.4	502	268	53.4	22.0	51	227	166	33.1
103	1568	727	55.1	1061	216	20.5	34.6	73	254	159	14.9
104	1090	1046	96.0	901	281	30.9	65.1	31	281	250	23.0
109	485	557	115.3	546	195	49.0	66.3	140	159	19	4.8
110	590	447	75.8	504	230	34.6	41.2	46	102	56	9.9
111	650	478	75.9	552	254	47.7	28.2	11	54	43	8.1
112	621	562	90.5	537	302	65.5	27.0	8	30	22	4.5
115	241	471	195.4	215	502	191.0	44.4	25	35	10	4.7
116	120	357	297.5	105	256	243.8	55.7	1	15	14	15.5
120	175	187	106.9	165	155	93.9	13.0	1	4	3	1.7
124	652	179	27.7	643	146	24.1	3.6	9	5	-4	0
130	505	551	70.8	525	349	66.7	5.9	54	54	20	5.8
132	496	309	62.3	467	241	48.3	20.0	40	0	0	0
137	465	381	82.5	290	118	40.4	41.9	10	10	0	0
	Dosing Changed From 8 Times Per Day to 6 Times Per Day (6 Times in 15 Hours With a 9-Hour Rest Period-Loading 7.8 gpd/sq ft)										
145	524	469	89.5	495	324	65.7	25.8	21	40	19	5.8
152	484	351	68.4	442	179	40.5	28.2	47	48	1	0.2
157	598	398	70.5	506	179	32.8	37.5	57	136	79	14.5
164	506	304	60.1	430	147	34.3	30.2	10	19	9	1.8
171	504	338	67.1	444	157	35.4	31.7	5	14	11	2.5

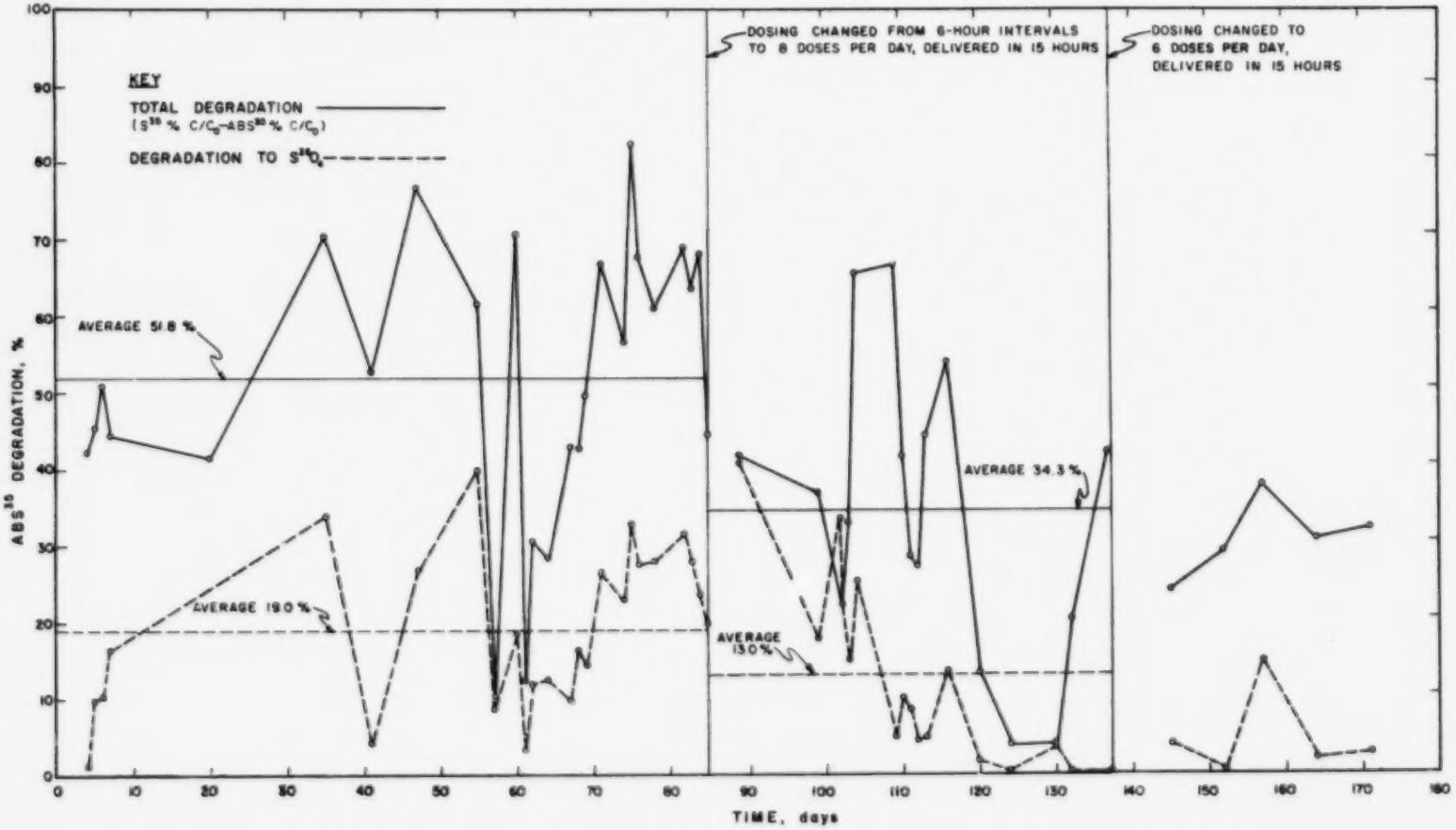

KEY
TOTAL DEGRADATION
(S^{35} % C/C_0 – ABS^{35} % C/C_0)
DEGRADATION TO $S^{35}O_4^=$
DOSING CHANGED FROM 6-HOUR INTERVALS TO 8 DOSES PER DAY, DELIVERED IN 15 HOURS
DOSING CHANGED TO 6 DOSES PER DAY, DELIVERED IN 15 HOURS
AVERAGE 51.8 %
AVERAGE 19.0 %
AVERAGE 34.3 %
AVERAGE 13.0 %
ABS^{35} DEGRADATION, %
TIME, days

FIGURE 4. DEGRADATION OF ABS^{35} IN OAKLEY SAND COLUMN INTERMITTENTLY DOSED WITH SEPTIC-TANK EFFLUENT

Upon increasing the dosing frequency and loading on day 85, there was no immediate change in degradation, and after 115 days individual values still exceeded 50 per cent. However, in the next few days clogging became severe, as indicated by excessive ponding. The effect on degradation was striking and declined to less than 5 per cent by the 124th day. Although average degradation for the entire period was 34.3 per cent as shown in Figure 3, from day 120 to 137 it averaged only 12.5 per cent. On the same basis values for degradation to sulfate were even more drastically reduced--from 13.0 per cent to 1.1 per cent. By this time the soil system had essentially failed in terms of removing ABS, as a direct result of overloading, followed by ponding and then by an anaerobic soil condition.

On day 137 the column was drained and rested overnight to restore aerobic conditions in the soil. Percolation was resumed on a schedule of 6 doses per day delivered in 15 hours. Loading was reduced to 7.8 gpd/sq ft or slightly less than during the initial 85-day period. The column gradually regained its infiltrative capacity and ABS^{35} degradation slowly increased. Still the average was only 30.3 per cent from day 137 to 171 with $S^{35}O_4$ degradation increasing slightly to 4.6 per cent giving indication that the system was not likely to approach the level of degradation attained at the 4-dose-per-day schedule. Therefore, the increase in dosing frequency from 4 to 6 times per day was detrimental to degradation even though hydraulic loading was reduced. The experiment was ended when it appeared unlikely that the system would be restored to its original efficiency.

Discussion

On a comparative basis the column receiving septic-tank effluent degraded ABS more efficiently than the primary-effluent column. At an equivalent loading of 8.3 gpd/sq ft degradation in the former system was over 50 per cent compared to less than 10 per cent in the badly clogged primary-effluent column. This difference in degradability is attributed to the difference in clogging characteristics of the two wastes which is a direct result of suspended solids removal efficiency during pretreatment.

Because of the critical effect of this physical difference in wastes, it is difficult to determine whether other waste characteristics of a biological or chemical nature have an influence on ABS degradation. Evidence that septic-tank effluent may be more amenable to degradation is suggested by the relative rapidity with which a sizable degree of degradation was attained in the septic-tank effluent soil column. It may be that the septic tank "conditions" sewage by partial anaerobic decomposition. Septic-tank effluent would then contain substrate readily available to soil microorganisms, resulting in a comparatively rapid slime growth.

Once an active biological slime was present in the soil, ABS degradation exceeded 50 per cent in both columns. The ultimate determinants of degree of degradation in soils are apparently frequency of

application and hydraulic loading rather than the character of the waste applied. Maximum degradation occurred with primary effluent, but only at a quite diminished loading compared to the load received by the septic-tank effluent column. With proper adjustment of loading, any waste containing suitable substrate for soil bacteria can create a biofilter system capable of excellent ABS degradation.

Conclusions

From the standpoint of physical characteristics, septic-tank effluent is more amenable to percolation through soil systems than is primary effluent due to a lower suspended solids concentration.

Growth of a biological slime is accelerated by septic-tank effluent. This may be due to the purely physical factors mentioned above, or possibly to partial anaerobic decomposition in the septic tank.

Once an active biological growth is established, extent of ABS degradation is governed by loading factors rather than by waste characteristics.

When dosing frequency is greater than four times per day, ABS degradation is reduced at a given hydraulic loading. For septic tanks which are dosed with a greater frequency than this, loading must be adjusted by the size of percolation fields to prevent ponding and loss of degradation efficiency.

WASTE CHARACTERISTICS

Introduction

Previous studies have indicated that septic-tank treatment may effect a significant change in sewage, either on the ABS molecule or on the chemical and biological environment, which accelerates degradation during subsequent aerobic treatment. In soil studies this effect was somewhat masked by the overriding physical difference between sewage subjected to septic-tank treatment and sewage treated by primary settling. To avoid the effect of suspended solids concentration and directly evaluate whether other biological or chemical factors were involved in enhancing ABS degradation of a particular waste during aerobic treatment, soil columns were abandoned in favor of direct aeration.

Procedure

Two-liter capacity graduated cylinders were employed to contain the sewage effluents. Effluent from the model septic-tank and sedimentation-tank effluent filled each of the cylinders. Tracer ABS^{35} was directly added to the primary effluent, and was present in the septic-tank effluent as a result of its addition to influent sewage fed into

the model septic tank. A small spherical air diffusion stone was inserted into each cylinder, and the wastes were gently aerated during the experimental period.

Samples were withdrawn from the midpoint of the liquid column height to avoid error due to concentration gradients. During the first month samples were taken three times per week and then for the remainder of the 63-day experiment, on a once-per week schedule. Volume loss due to evaporation was replenished by addition of tap water to the cylinders before samples were withdrawn. Individual samples were analyzed for S^{35}, ABS^{35}, and $BaS^{35}O_4$ activity and results were corrected for radioactive decay.

Despite the fact that aeration was kept at an absolute minimum, during the first day of operation a small head of foam formed above the liquid surfaces and so reduced ABS^{35} concentration in the body of the liquid. For this reason samples taken on the second day, after an equilibrium was established, were used to represent the initial liquid activity concentration (C_o).

Results

The rate of degradation was determined by the difference between loss of S^{35} activity of the effluent and loss of ABS^{35} activity. In Tables III and IV it can be seen that there is a loss in S^{35} activity over the experimental period, which is attributable to physical ejection with froth. Dried froth on the cylinder walls was noticeable and was responsible for removal of activity from the system. Over the experimental period the loss is seen to fluctuate somewhat--which in part may be due to reimmersion of removed activity and partially due to experimental error.

To eliminate this loss from degradation computations, it was necessary to subtract the per cent of intact detergent (ABS^{35}, $\% C/C_o$) from the per cent remaining total activity (S^{35}, $\% C/C_o$) in a given sample. The difference obtained excludes physical loss of activity from the system, and thus represents biodegradation only.

In Figures 5 and 6 the S^{35}, ABS^{35}, and $BaS^{35}O_4$ activity are plotted for the two wastes and show the activity curves to be quite similar. Degradation to inorganic sulfate is very nearly the same in both wastes (about 25 per cent for septic-tank effluent and about 30 per cent for primary-sewage effluent).

In Figure 7 it is again evident that septic-tank effluent ABS degrades more rapidly at the outset of aerobic treatment since after two weeks it was 30 per cent degraded compared to no degradation in primary sewage. However, a sharp upsurge in ABS degradation of the latter waste occurring on day 16 brought it to the same level as the septic-tank effluent. From this point until the end of the experiment ABS degradation was virtually the same for both wastes, being on the order of 60 per cent on the final test day.

TABLE III

DEGRADATION OF ABS^{35} IN AEROBIC SEPTIC-TANK EFFLUENT

Day	S^{35}		ABS^{35}		ABS^{35} Degradation (S^{35}, C/C_o - ABS^{35}, C/C_o)	$BaS^{35}O_4$ (complete Degradation)	
	cpm/ml	%, C/C_o	cpm/ml	%, C/C_o	%	cpm/ml	%, C/C_o
1	595	100	583	100	98	15	2.2
6	644	108.2	487	83.5	24.7	9	1.5
8	610	102.5	457	78.4	24.1	13	2.2
13	644	108.2	399	68.4	39.8	23	3.9
16	497	83.5	302	51.8	31.7	29	5.0
20	417	70.1	224	38.4	31.7	16	2.7
30	423	71.1	143	24.5	46.6	34	5.8
42	394	62.2	108	18.5	43.7	124	21.3
56	385	64.7	87	14.9	49.8	138	23.7
63	408	68.7	65	11.1	57.6	140	24.0

TABLE IV

DEGRADATION OF ABS^{35} IN AEROBIC PRIMARY SEWAGE EFFLUENT

Day	S^{35}		ABS^{35}		ABS^{35} Degradation (S^{35}, C/C_o - ABS^{35}, C/C_o	$BaS^{35}O_4$ (complete Degradation)	
	cpm/ml	%, C/C_o	cpm/ml	%, C/C_o	%	cpm/ml	%, C/C_o
1	706	100	565	100	0	0	0
6	653	92.5	530	93.8	-1.3	7	1.2
8	639	90.5	477	84.4	6.1	16	2.8
13	503	71.2	422	74.7	-3.5	27	4.8
16	674	95.5	331	58.6	36.9	31	5.5
20	656	92.9	236	41.8	51.1	42	7.4
30	522	73.9	201	35.6	38.3	88	15.6
42	555	78.6	174	30.8	47.8	135	23.9
56	590	83.6	133	23.5	60.1	185	32.7
63	600	85.0	127	22.8	62.2	180	31.9

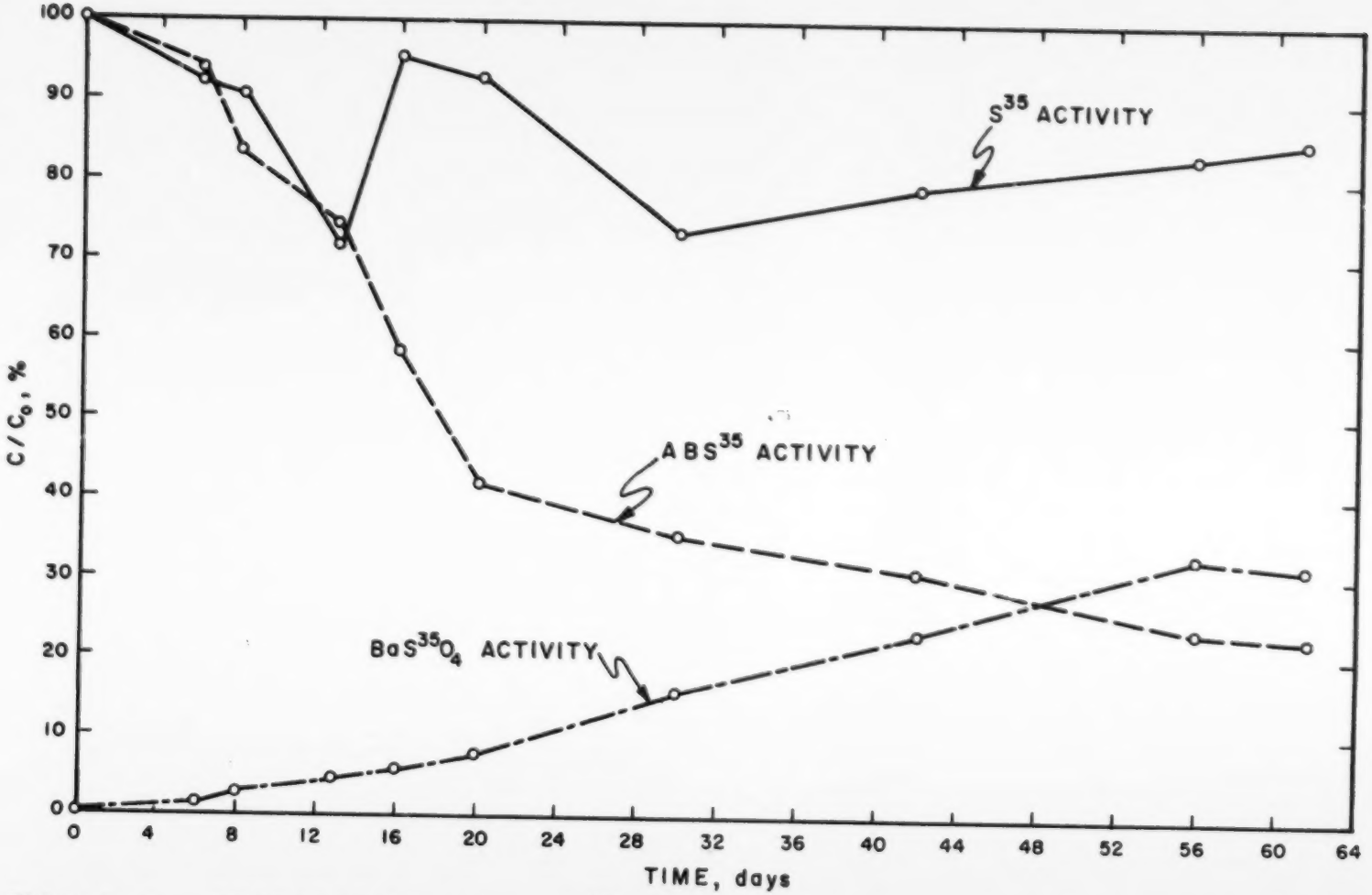


FIGURE 5. DEGRADATION OF ABS^{35} IN AEROBIC PRIMARY-SEWAGE EFFLUENT

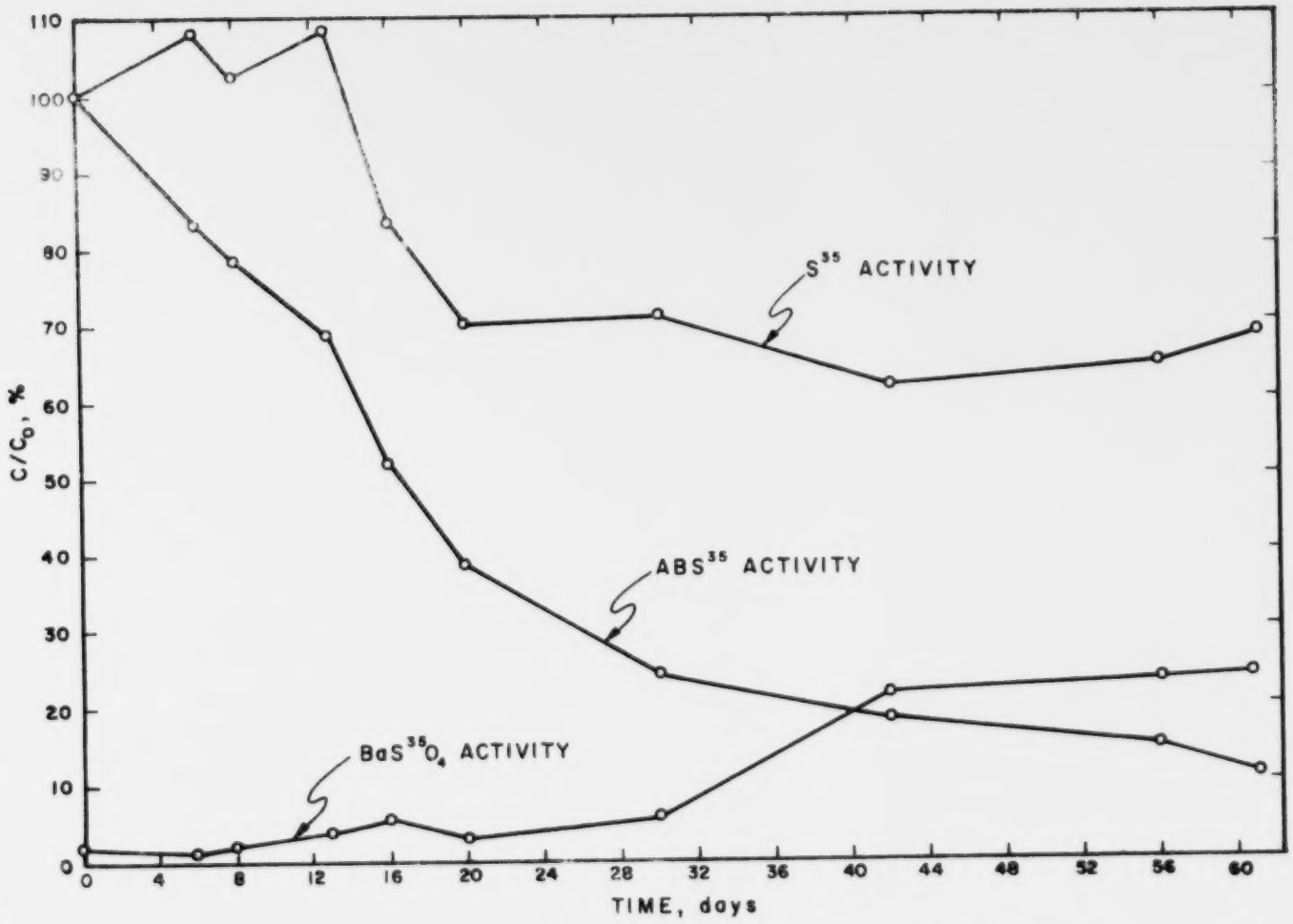


FIGURE 6. DEGRADATION OF ABS^{35} IN AEROBIC SEPTIC-TANK EFFLUENT

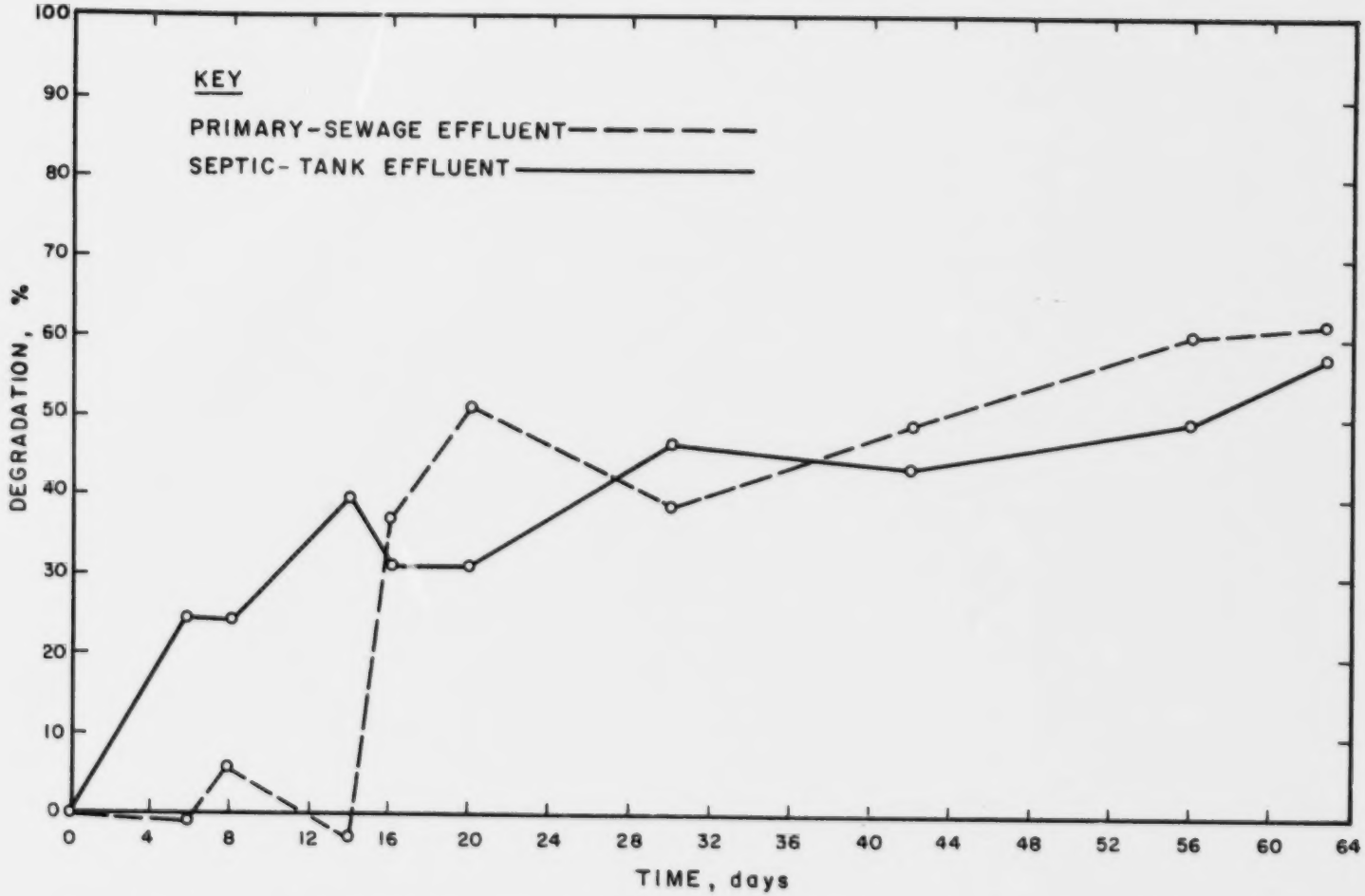


FIGURE 7. COMPARISON OF ABS^{35} DEGRADATION IN AEROBIC SEPTIC-TANK EFFLUENT AND AEROBIC PRIMARY-SEWAGE EFFLUENT

Discussion

These results confirm the "conditioning" theory of septic-tank treatment. This is evident from the fact that ABS in effluent derived from septic tanks is more readily degraded in subsequent aerobic treatment compared to primary effluent. Rapid formation of a flourishing bacterial population during the aeration treatment indicates that partial decomposition of organic matter in the septic tank did occur, and yielded an effluent containing readily acceptable substrate for bacteria. This explanation is supported by the fact that ABS in both wastes eventually became degraded to the same extent, suggesting that the initial lag in bacterial activity in primary effluent is gradually overcome and becomes equal when the population reaches the logarithmic growth phase.

Conclusions

It may be concluded than that both from a physical and biochemical standpoint septic-tank effluent is a more acceptable medium for subsequent aerobic ABS degradation than is primary effluent.

Ultimate degradation is equal in both wastes after an initial bacterial activity lag is overcome in primary effluent.

SEPTIC TANK STUDY

Introduction

Ground water contamination by detergents, particularly in areas where household septic tanks are prevalent, indicates that passage of significant but unknown quantities of ABS through these systems is possible under field conditions. Determination of ABS survival in septic tanks was therefore undertaken in this experiment to obtain needed background information on polypropyl ABS degradation. Results are especially pertinent as a reference for comparison with removal efficiency of "soft" detergents, which are soon expected on the market.

Procedure

The model septic tank (see Figure 1) was operated for 80 days by intermittent dosing to simulate discontinuous loading in actual practice. Sewage was drawn from the previously described intake through two solenoids, which released doses six times in 16 hours each day. The solenoids were activated by a programmed timer to release doses at the following times each day: 0033, 0850, 1047, 1408, 1613, and 1828 hours. Nine liters of sewage were delivered per dose, or 54 liters per day. Since the septic-tank capacity was 45.7 liters, the theoretical detention time was 20 hours.

Tracer ABS^{35} was injected into the sewage stream by a Sigma pump operated simultaneously with the solenoids. The point of injection was

near the head tank to allow mixing of tracer and sewage throughout the length of the influent line. No additional carrier detergent was added to that already present in the influent sewage.

Influent samples were withdrawn at the entrance port to the septic tank. Composite samples were taken by a Sigma pump operated in series with the solenoids. Septic-tank effluent samples were also composited in the same manner. Preservation during the compositing period was effected by acidification with 2 ml of concentrated HCl per liter of sample.

Twice a week influent and effluent samples were analyzed for S^{35}, ABS^{35}, and $BaS^{35}O_4$ activity. Methylene blue determinations of ABS were also made for purposes of compariosn with radioassay.

The efficiency of the septic tank as a sewage treatment unit was determined by COD and suspended solids measurements.

Results

Activity Breakthrough. Figure 9 presents the breakthrough of S^{35} and ABS^{35} activity through the tanks expressed as the percentage of influent activity appearing in the effluent. Instead of a typical S^{35} breakthrough curve increasing steadily to 100 per cent, the curve rose and fell erratically throughout the experimental period of 80 days. Since the detention period was only 20 hours, obviously a complete breakthrough had to occur within a very few days. It bacame obvious as the experiment progressed that the problem was in obtaining an accurate influent sample. Tracer was not mixing adequately with influent sewage in the line due to laminar flow. This affected results insofar as computation of total ABS removal was concerned, but did not affect determination of ABS degradation.

A device was installed between the tracer injection point and the sampling point to create turbulent flow. It consisted of a series of pipes ranging in diameter from 1/8 to 3/4 inch and connected by bell reducers. Although this device was successful in creating turbulent flow, the smaller diameter pipes clogged repeatedly with sewage solids. In view of the fact that degradation could be accurately determined without this installation, it was removed from the system.

ABS Degradation. Although influent samples were nonrepresentative with regard to the actual cpm per ml of S^{35} and ABS^{35}, the samples were representative of the ratio of S^{35} to ABS^{35} cpm per ml. Therefore, when the ratio of ABS^{35} influent activity appearing in the effluent is subtracted from the S^{35} ratio, the resultant value for degradation is valid. As may be seen in Figure 8 the S^{35} and ABS^{35} breakthrough curves are virtually the same indicating that degradation was minimal in the septic tank. The average for the test period was 1.7% (see Table V).

ABS Removal. ABS removal by adsorption on settleable solids could not be determined by radioassay because of the sampling problem. This

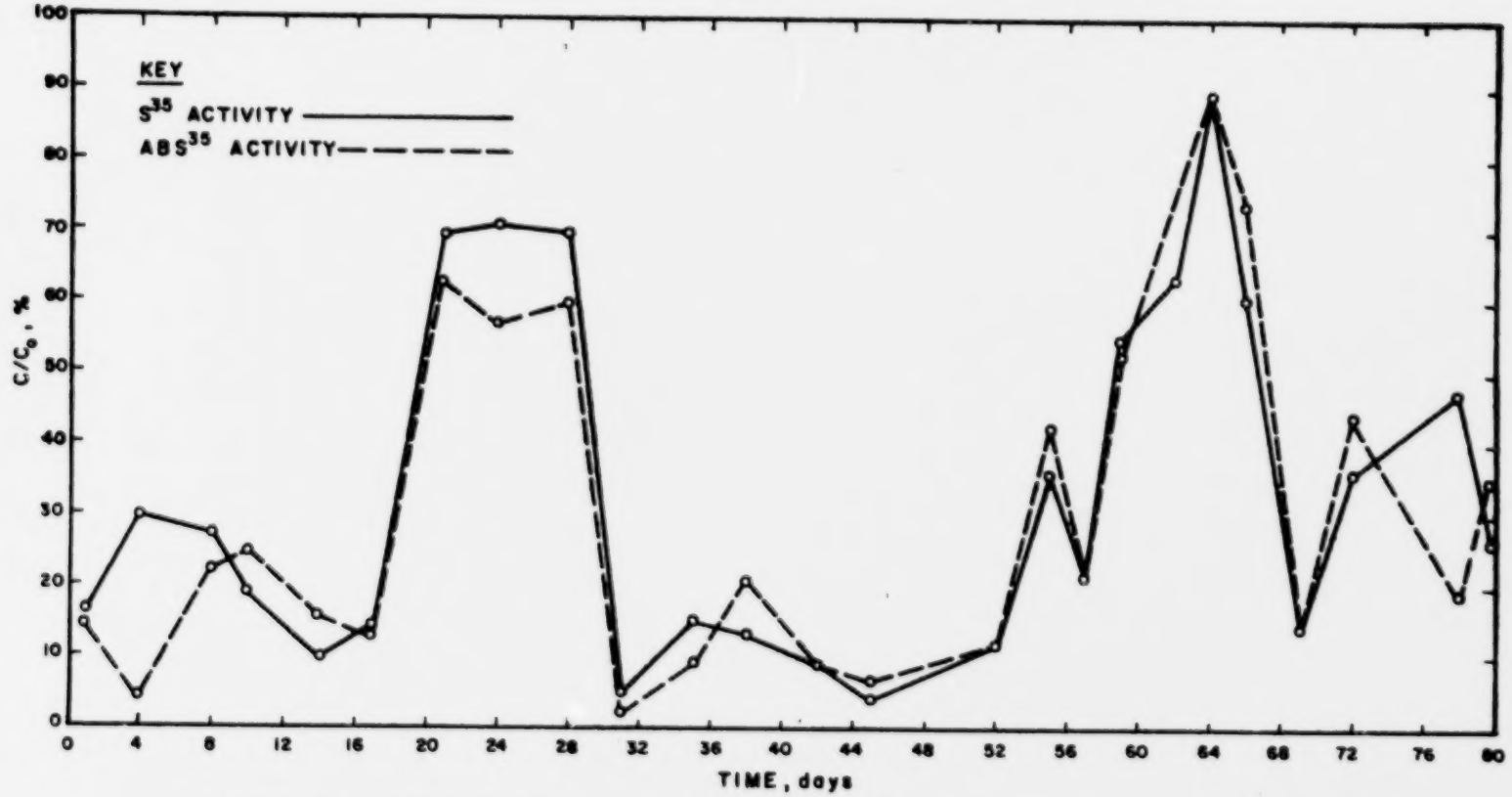


FIGURE 8. BREAKTHROUGH OF S^{35} AND ABS^{35} ACTIVITY THROUGH SEPTIC TANK

TABLE V

EFFECT OF SEPTIC-TANK TREATMENT ON ABS^{35}

Day	Total S^{35} Activity (C/C_o, %)	ABS^{35} Activity (C/C_o, %)	$BaS^{35}O_4$ Activity		ABS^{35} Degradation (S^{35}, C/C_o - ABS^{35}, C/C_o) %	ABS		
			Influent cpm/ml	Effluent cpm/ml		Influent mg/l	Effluent mg/l	C/C_o %
1	16.1	14.4	6	0	1.7	3.6	2.8	77.9
4	29.7	4.4	3	2	25.3	--	--	--
8	26.7	22.3	0	0	4.4	--	--	--
10	18.7	24.6	5	5	-5.9	4.8	3.5	72.9
14	9.8	15.2	13	6	-5.4	6.5	5.2	84.0
17	14.1	12.9	13	1	1.2	5.6	5.0	89.4
21	69.0	62.4	5	2	6.6	6.0	3.9	65.0
24	70.5	56.4	--	--	14.1	8.2	5.4	65.9
28	69.5	59.7	4	0	7.8	6.2	5.3	85.5
31	4.8	2.0	41	1	2.8	--	--	--
35	14.8	7.6	20	1	7.2	4.7	4.5	95.9
38	12.7	20.2	46	3	-7.5	6.9	5.0	72.5
42	9.1	8.3	68	7	0.8	5.9	5.4	91.6
45	4.2	5.8	83	4	-1.6	5.6	5.8	103.5
52	11.9	11.5	31	4	0.4	--	--	--
55	36.1	42.5	12	0	-6.4	--	--	--
57	21.1	22.3	33	5	-1.2	--	--	--
59	54.4	52.4	5	3	2.0	--	--	--
62	63.0	75.1	5	3	-12.1	--	--	--
64	88.7	88.5	4	3	0.2	--	--	--
66	60.2	73.9	11	3	-13.7	--	--	--
69	14.2	14.4	33	2	-0.2	--	--	--
72	36.0	38.7	14	3	-2.7	--	--	--
78	47.3	17.9	14	14	29.4	--	--	--
80	26.3	34.7	28	17	8.4	--	--	--
Avg.	33.2	31.5	21	4	1.7	5.8	4.7	81.0

[a] Methlene blue determinations

removal is normally taken at steady state as the difference between total activity (S^{35}) breakthrough and 100 per cent.

An estimate of adsorbed ABS may be made from other data. It has been determined in previous studies [2] that only 10 per cent of the influent ABS is associated with sewage solids, therefore this is the maximum amount of ABS that could be removed by sedimentation in the septic tank. In standard primary treatment of 2-hour duration, ABS removal was found to be 2 per cent. The more efficient suspended solids removal in a septic tank (20-hour residence) would be expected to result in improved ABS removal compared to primary treatment. Since 50 per cent of the suspended solids are normally removed in septic tanks and 10 per cent ABS is associated with these solids, it is probable that about 5 per cent ABS removal would occur.

$BaS^{35}O_4$ Reduction. In Table V it is evident that $BaS^{35}O_4$ is reduced in the septic tank, as would be expected in anaerobic treatment. An average of 4 cpm per ml $BaS^{35}O_4$ in the effluent shows that this reduction of sulfate is nearly complete.

Colorimetric Determination. Colorimetric ABS determinations are also shown in Table V. The average breakthrough of intact ABS was 81.0 per cent, or conversely, 19.0 per cent ABS removed. This removal includes both adsorption and degradation. Higher ABS removals are expected by colorimetry than by radioassay, because of the presence in raw sewage of more positive than negative interferences which complex with methylene blue to give an erroneously high ABS influent reading.

Since a considerable amount of these interferences are removed in the septic tank, the net effect is an apparently greater ABS removal than is actually obtained.

Parameters of Septic-Tank Performance. Suspended solids and COD determinations were run in accordance with Standard Methods [4] and the removals effected by the septic tank are shown in Table VI. Average per cent removals are 59.0 and 40.0, respectively, indicative of a properly functioning unit.

It is interesting to note that the septic tank has a stabilizing effect. In Figures 10 and 11 it is evident that despite gross fluctuations in influent concentrations, the effluent produced was quite stable with regard to COD and suspended solids. Therefore, from the standpoint of per cent removal alone, septic tank performance appears improved as the strength of the influent sewage increases, but effluent quality remains nearly constant regardless of influent strength.

Conclusions

It may be concluded then that normal ABS degradation in septic-tank treatment is about 2 per cent. Furthermore, total removal by adsorption and degradation is not likely to exceed 10 per cent. Although colorimetric measurements show a higher ABS removal of 19 per cent,

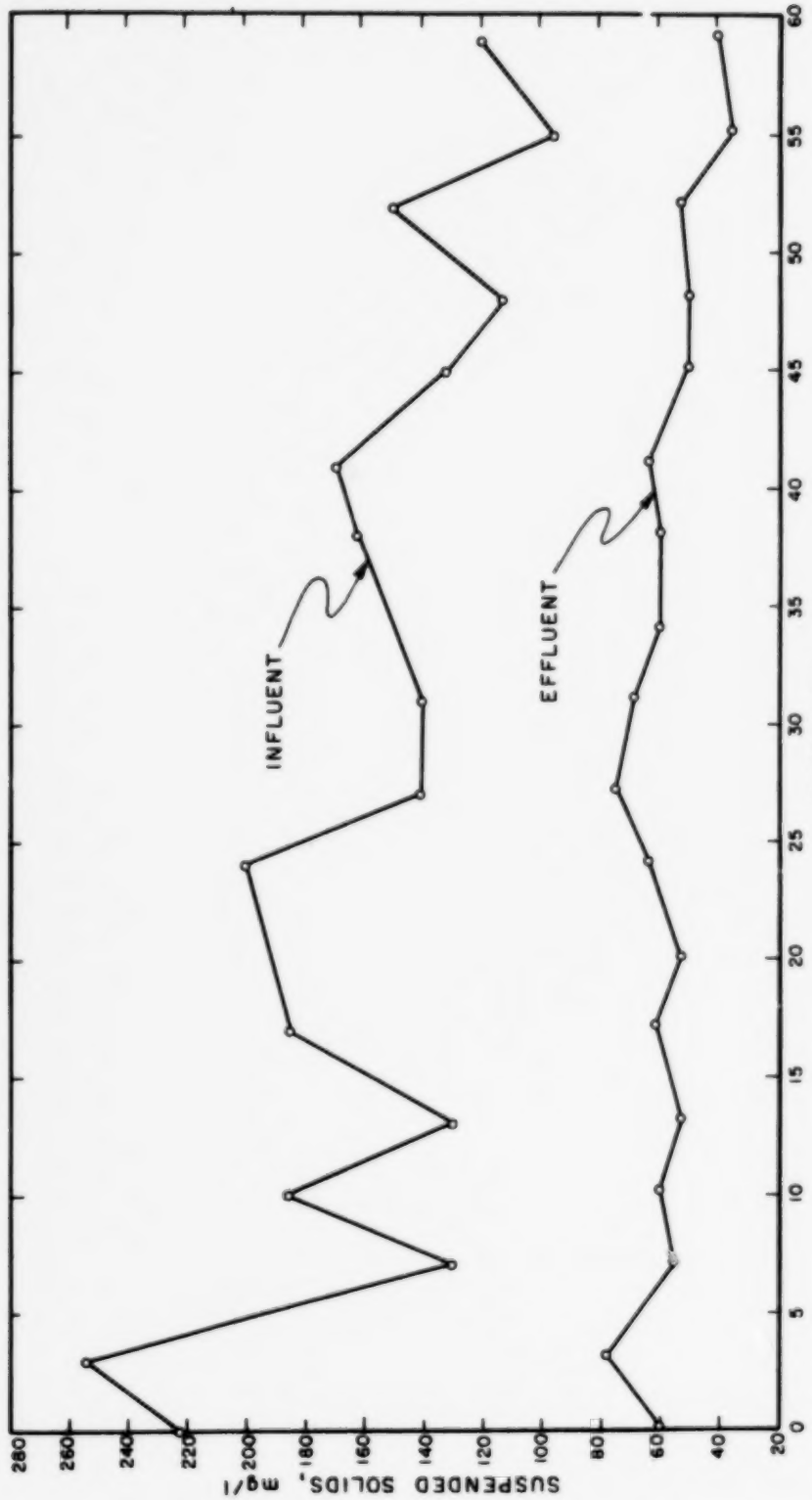


FIGURE 9. SUSPENDED SOLIDS REMOVAL IN SEPTIC TANK

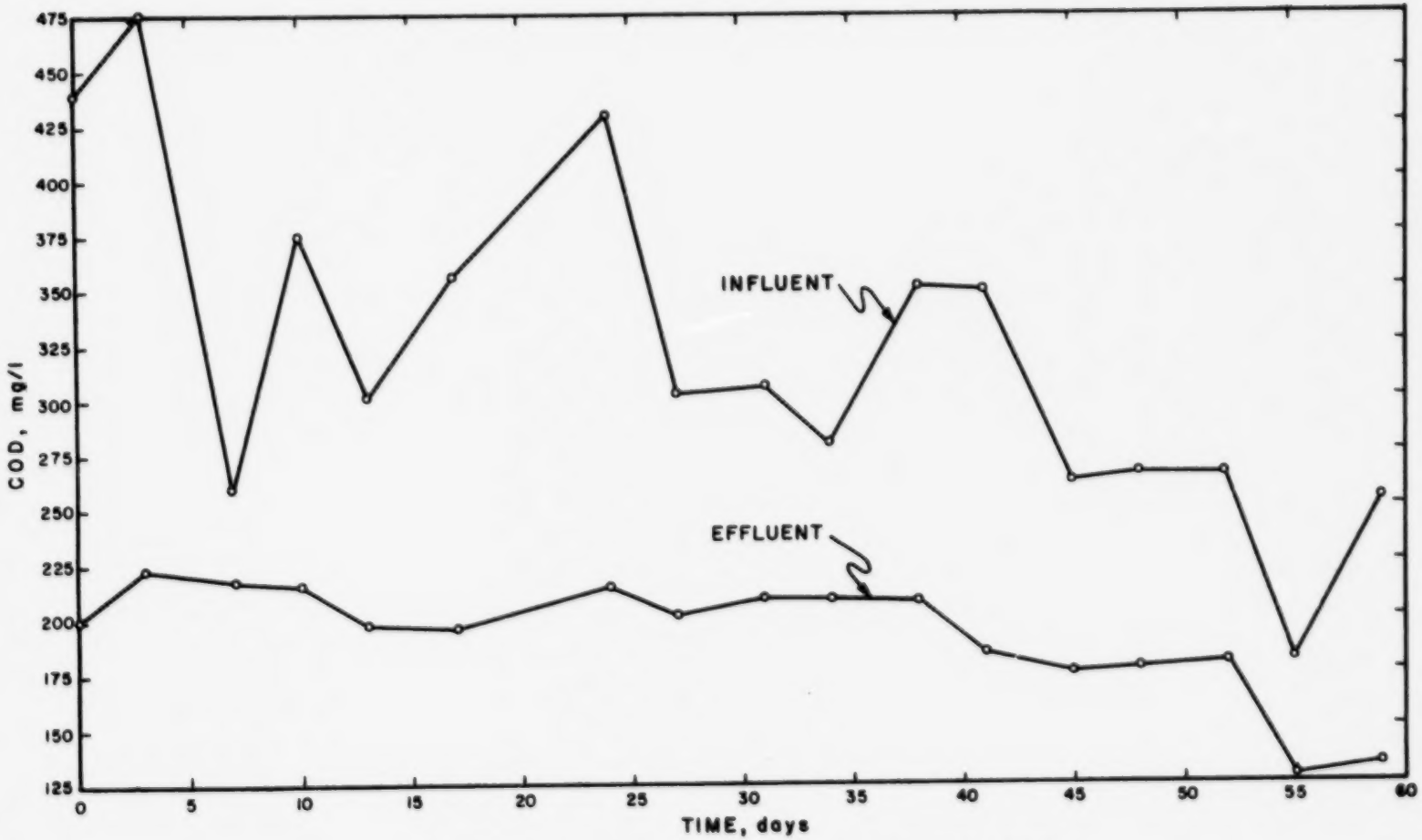


FIGURE 10. COD REMOVAL IN SEPTIC TANK

colorimetry exaggerates removals due to the predominance in raw sewage of positive interferences which are removed to a large extent in the septic tank. Expected anaerobic behavior is reflected in reduction of influent sulfate through the system.

TABLE VI

PARAMETERS OF SEPTIC-TANK PERFORMANCE

Day	Suspended Solids			COD		
	Influent mg/l	Effluent mg/l	Removal %	Influent mg/l	Effluent mg/l	Removal %
0	222	61	76.0	438	200	54.4
3	254	79	69.0	476	222	53.3
7	110	79	49.0	260	218	16.1
10	166	60	64.0	374	215	42.5
13	110	53	51.8	301	198	34.2
17	165	62	62.5	355	191	46.2
20	--	53	--	--	199	--
24	200	64	68.0	428	214	50.0
27	121	75	38.0	302	201	33.4
31	120	69	42.6	304	208	31.5
34	--	60	--	279	208	25.4
38	142	59	58.5	350	207	40.9
41	149	63	57.6	349	183	47.6
45	112	50	55.3	262	175	33.2
48	93	49	47.4	265	177	33.1
52	130	53	49.2	265	179	32.4
55	75	35	53.4	180	126	30.0
59	100	39	61.0	253	133	47.5
Avg.	142	58	59.0	320	192	40.0

IV. SUMMARY AND CONCLUSIONS

ABS degradation was assessed by radioassay in wastes percolated through laboratory-scale soil columns at various dosing frequencies and several hydraulic loadings. Both primary-sewage effluent and septic-tank effluent were evaluated to determine whether waste characteristics were critical to ABS degradation in soils.

It was found that at equivalent loadings septic-tank effluent was more amenable to infiltration through soil than primary effluent. Superior infiltrative qualities were attributed to the longer residence period in septic tanks resulting in more efficient suspended solids removal. Consequently, when this waste was spread on soil there was less tendency to pond and create an anaerobic condition which inhibits ABS degradation.

When loadings were adjusted to avoid ponding both wastes were ultimately capable of the same degree of degradation. However, septic-tank effluent was again far superior at the outset of waste spreading. After only a few days considerable degradation was occurring in this soil column, but nearly two months were required for comparable degradation in the primary-effluent column. This difference was due to rapid growth of a biological slime induced by septic-tank effluent. The cause of accelerated growth was only partially attributable to the physical difference of suspended solids concentrations affecting percolation. A significant contributing factor was the biochemical difference in the two wastes. This was found by comparing degradation during aeration under conditions which were independent of suspended solids concentration. Degradation was again virtually immediate in septic-tank effluent and delayed for primary effluent. This indicates that the septic tank "conditions" sewage by partial decomposition of organics making a more suitable substrate for bacterial growth.

Once an active biological growth is developed, loading factors rather than waste characteristics govern the extent of ABS degradation. When the dosing frequency was limited to 4 times per day, maximum degradation of nearly 70 per cent occurred. There was no significant difference in degradation when only one dose per day was applied at the same hydraulic loading. At dosing intervals of six and eight times per day degradation was inhibited by ponding, requiring reduction in hydraulic loading to restore ABS removal efficiency.

In studies of ABS passage through a model septic tank it was found by radioassay that only 2 per cent degradation occurs, and total removal due to degradation and adsorption is not likely to exceed 10 per cent. Colorimetric measurements indicate a removal of 19 per cent; however, the methylene blue method of ABS determination in sewage is usually subject to more positive than negative interferences. Removal of these interferences in the septic tank would therefore tend to exaggerate the ABS removal efficiency.

Future studies are planned to compare the degradation of polypropyl ABS to experimental "soft" detergents (provided by the Soap and Detergent Association) in septic tanks and percolation fields. These materials will also be evaluated in trickling filters and activated sludge units by radioassay techniques.

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